Low Chlorine Residual and Intermittent Flow Lead to Coliforms Presence: A Study Case on Banda Aceh Water Supply System

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Abstract Even though the water is supplied from Water Treatment Plant 24 hours a day, some consumers of Tirta Daroy Water Supply Company receive water in their taps intermittently. This condition leads to several reported pipe breaks and coliforms presence, as well. Tirta Daroy conducts a quality control activity so called Pamkor on regular basis. This study is conducted to analyse data obtained from this activity during 2014, with the focus on the total coliforms for total 161 sampling connections. The result demonstrates that the coliforms presence is encouraged by the low chlorine residual and intermittent supply. Additional finding shows these two conditions occur mainly at the areas which have long distance to the water treatment plant.
Keywords Intermittent Flow, Coliforms, Chlorine Residual, Chlorination

Introduction

Tirta Daroy Water Supply Company (Indonesian: PDAM Tirta Daroy) is a municipal water supply company serving the area of Banda Aceh City. The raw water is extracted from Krueng Aceh River (SDC and PT NWC, 2007) which is situated approximately 8 km from the outside border of Banda Aceh City, and then processed at two Water Treatment Plants (WTPs), namely Lambaro and Siron, prior to the distribution.

The treatment process in Lambaro WTP consists of several sedimentation and filtration stages, using Aluminum sulphate (alum) as coagulant, and chlorine solution to maintain the treated water quality during storage and distribution (SDC and PT NWC, 2007). The Quality Control Section of Tirta Daroy conducts a routine, sampling quality check so called "Pamkor" to house connections to ensure adequate water quality at the consumer taps. In addition to several physical parameters measurement, this activity aims likewise to detect coliforms and *Escherichia coli* presence in samples. Coliforms have been used for many decades as the indicator of choice for drinking water, in order to assess

water treatment effectiveness and the integrity of the distribution system (Cohn, et al., 1999).

United Nation Environment Programme (2006) defines coliforms bacteria as collection of relatively harmless micro-organisms living in large numbers in the intestines of man and warm- and cold-blooded animals. Based on Indonesian national regulations, the presence of both coliforms and *E. coli* is limited to zero on all samples (Menteri Kesehatan RI, 2010). This study is conducted to analyse data obtained from *Pamkor* activity during 2014, in term of total coliforms and *E. coli* presence for the total 161 samples.

Intermittent Flow Encourages Bacterial Growth

Lambaro WTP is designed to produce and supply water continuously 24 hours a day. Yet, most of consumers receive water intermittently. This condition is very common in developing countries. One of the main causes is due to low supply pressure (Ratnayaka, et al., 2009). The low pressure occurs especially in the area where is far from installation, as the consequence of head loss during transportation. In an intermittent supply situation, the consumers typically secure their water supply through the use of ground or roof tanks, which are filled during the time that the supply is provided (Charalambous, 2011). However, the majority of Tirta Daroy consumers prefer to install a house pump connected directly to the connection pipes, instead of ground tanks, in order to fulfil their water demand. Consequently, it disturbs the flow design, and lead to worsen the intermittent flow for consumers without house pump installation.

The intermittent supply is in general avoided in a water supply system, because it leads to several deficiencies. Charalambous (2011) mentioned that based on case study data has shown that there was a large increase in the number of reported pipe breaks during periods of intermittent supply. If the water is flowed intermittently, the resulting low water pressure will also allow the ingress of contaminated water into the system through breaks, cracks, joints and pinholes, leading to serious risks to health (World Health Organization, 2011; Ratnayaka, et al., 2009; Nagari, 2003). On the other hand, with intermittent supply condition, leak

detection mechanism is very difficult (Ratnayaka, et al., 2009). This condition also applies to Tirta Daroy, where some pipe breaks has been reported, especially in the areas which have long distance to WTP. Combined with the house pump installation, the unseen pipe breaks are nearly undetectable.

The Use of Chlorination as Disinfection

Total coliforms are commonly used to show the possible presence of microbial contamination from human waste in form of faecal contamination, which the major subset is *E. coli* (Cohn, et al., 1999; Pontius, et al., 2005). A comprehensive water quality monitoring program should be conducted throughout distribution systems for several parameters, including chlorine residual, bacteriological and physical measurements (Hesby, 2005). And if any of samples test positive for coliforms bacteria, a further test to detect *E. coli* presence should be conducted (Vacs Renwick, 2013).

Like most of water supply companies in developing country, Tirta Daroy uses chlorination as disinfecting process for bacterial growth in supplied water. Since chlorination has a lasting residual effect, is relatively easy to handle and cost effective, its use in drinking-water has been proven effectively for inactivation of microbial pathogens for nearly 100 years (World Health Organization, 2004; Gray, 2005). Most individuals are able to taste or smell chlorine odour in drinking-water at concentrations well below 5 mg/l, and some at levels as low as 0.3 mg/l (World Health Organization, 2011). But interestingly, in spite of its unpleasant odour, some individuals will assume the water is not safe to drink unless they smell chlorine odour (Dietrich, 2006). Regarding the health issue, there is no evidence that the levels of chlorine residual normally found in drinking water are harmful to health (Ratnayaka, et al., 2009). Tirta Daroy targets the chlorine residual at the end connection should be more than 0.2 mg/l in order to avoid the bacterial growth in the supplied water.

Pamkor 2014 Result and Analysis

This study evaluates 161 samples taken during *Pamkor* activity on 2014. Pamkor activity provides: (1) basic information containing name of connections owner, ID number and address,

and (2) technical data containing turbidity, conductivity, Total Dissolved Solid (TDS), salinity, temperature, pH, chlorine residual, total detected coliforms, total E. coli and remarks regarding supply continuity. This study uses data describing the sampled connection's address, chlorine residual, total detected coliforms, total *E. coli* and supply continuity to do the analysis. The later data is obtained based on on-site interview to the connection owners.

The obtained samples during 2014 cover 40 out of 90 villages and all 9 sub-districts in Banda Aceh City. The sampling distribution on sub-districts (Table 1) shows a significant number of samples for Kutaraja, Syiah Kuala, Meuraxa, Ulee Kareng and Jaya Baru sub-districts, since these 5 sub-districts have distance to the treatment plants, hence, it is expected to have low chlorine residual due to loss during water transport. Therefore, the *Pamkor* activity took more samples on these sub-districts.

Table 1: Samples distribution on 9 sub-districts

Num.	Name of Sub-district	Number of Samples
1	Syiah Kuala	33
2	Ulee Kareng	15
3	Kuta Alam	8
4	Baiturrahman	1
5	Banda Raya	2
6	Lueng Bata	7
7	Jaya Baru	17
8	Kutaraja	48
9	Meuraxa	30
	Total	161

From these 161 samples, the chlorine residual value varies from 0.05 to 0.67 mg/l. In order to do the analysis, the chlorine residual value of all samples is classified into 4 groups, as presented on the following Table 2.

Table 2: Distribution of chlorine residual on all samples

Num.	Chlorine Residual (mg/l)	Number of Samples	Number of Samples With Coliform Presence	Percentage of Samples With Coliform Presence	Number of Samples With E.coli Presence
1	0.00 - 0.20	38	10	26%	0
2	0.21 - 0.50	114	0	0%	0
3	0.51 - 1.00	9	0	0%	0
4	>1.00	0	0	0%	0
	Total	**161**	**10**	**6%**	**0**

Based on the data, number of samples with chlorine residual range of 0.00 – 0.20 mg/l contributes to 38 samples, 35 of which are located at the 5 sub-districts having long distance to the treatment plants. Combined with the tropical condition as the samples water temperature are ranged of 27° - 32°, the long distances transport leads to microbial growth, as defined by World Health Organization (2011). Table 2 also shows that 10 of totally 38 samples with chlorine residual range of 0.00 – 0.20 mg/l have coliforms, while none is detected at other chlorine residual ranges. It supports the approach of research by Vacs Renwick (2013), who assumed the water will be coliform free if the average chlorine residual is above 0.2 mg/l, although The World Health Organization recommended a safer approach of minimally 0.5 mg/l chlorine residual after at least 30 minutes contact time. The later minimum value is also applied when potential waterborne disease occurs or when faecal contamination of a drinking-water supply is detected (World Health Organization, 2011; Ratnayaka, et al., 2009). However, in this study, there is no detection of coliforms or E. coli in the samples with chlorine residual of 0.21 – 0.50 mg/l.

Regarding the flow continuity data, not all respondents gave this kind of information. Hence, the flow continuity class in this study is distinguished into 4 classes, which are: continuous flow, slightly intermittent flow, very intermittent flow and undefined. The result and its correlation to coliform presence are shown on the following Table 3.

Table 3: Correlation between flow continuity and coliform presence

Num.	Flow Continuity	Number of Samples	Number of Samples With Coliform Presence	Percentage of Samples With Coliform Presence	Number of Samples With E.coli Presence
1	Continous	79	0	0%	0
2	Slightly intermittent	21	3	14%	0
3	Very intermittent	14	4	29%	0
4	Undefined	47	3	6%	0
	Total	**161**	**10**	**6%**	**0**

The result shows that the samples with continuous flow give zero result on the presence of coliforms and *E. coli*. The percentage of samples with coliform presence rises when the flow continuity is slightly intermittent and very intermittent, respectively. Furthermore, there are 3 out of 47 samples with undefined flow continuity having coliform presence. It is as expected, since the undefined flow should contain the samples with intermittent flow, beside the connections with continuous flow. In conclusion, continuous flow provides safest way to avoid bacterial presence in the supply system.

The intermittent flow at Tirta Daroy supply system occurs mainly due to electricity blackout and the use of house pumps by the consumers directly to the Tirta Daroy piping system. Based on interview to WTP technician, during the blackout, there is time interval of 10 to 15 minutes before the back-up generator runs. Additionally, the installed back-up generator is only able to accommodate 40% of normal operation of WTP. Hence, the available water in the piping system during the running of generator is not able to fulfil overall connection demand, especially when most of connections operate house pumps. A further study regarding the effect of house pump installation is suggested to be conducted.

Conclusion

Based on overall results, the combination of chlorine residual and flow continuity plays the most important role in coliforms presence. Should the chlorine residual is maintained above 0.2 mg/l and the supply is continuous, the supplied water is expected to have coliforms free. In addition, since the transport distance influences the chlorine residual, an additional chlorine injection for the long distance connections can be considered. Since the area with long distance connections will also need additional booster pump in order to maintain minimum design pressure, the additional chlorination can be done at this booster pump installation.

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